Air Force Successes & Challenges in Cr(VI) Elimination

10 May 2011

Dr. Elizabeth Berman
Senior Materials Research Engineer
AFRL/RXSC
937-656-5700
elizabeth.berman@wpafb.af.mil

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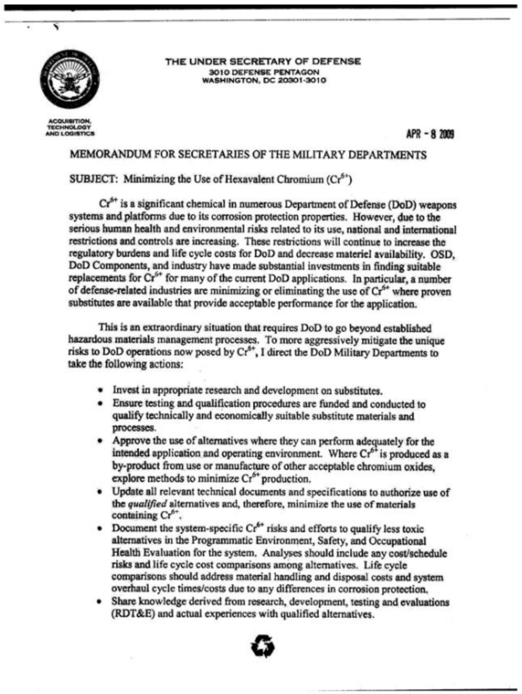
Background

- Cr(VI) has been used for 40+ years and is an excellent corrosion inhibitor
- Cr(VI) compounds are highly toxic
- National & International regulations and procedures are tightening on Cr(VI) use
  - i.e. OSD's Emerging Contaminants Action List
- DoD promoting use of Cr(VI) substitutes
  - Mr. J.J. Young, DUSD Memo of 8 Apr 2009
  - Use of Suitable Substitutes for Specific Applications is the default position
  - Waivers must be sought for continued use of Cr(VI)
- Suitable Substitutes for Specific Applications are being Actively Sought



THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

ACQUISITION, TECHNOLOGY AND LOGISTICS

APR - 8 2009

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS

SUBJECT: Minimizing the Use of Hexavalent Chromium (Cr^{6+})

Cr^{6+} is a significant chemical in numerous Department of Defense (DoD) weapons systems and platforms due to its corrosion protection properties. However, due to the serious human health and environmental risks related to its use, national and international restrictions and controls are increasing. These restrictions will continue to increase the regulatory burdens and life cycle costs for DoD and decrease materiel availability. OSD, DoD Components, and industry have made substantial investments in finding suitable replacements for Cr^{6+} for many of the current DoD applications. In particular, a number of defense-related industries are minimizing or eliminating the use of Cr^{6+} where proven substitutes are available that provide acceptable performance for the application.

This is an extraordinary situation that requires DoD to go beyond established hazardous materials management processes. To more aggressively mitigate the unique risks to DoD operations now posed by Cr^{6+}, I direct the DoD Military Departments to take the following actions:

- Invest in appropriate research and development on substitutes.
- Ensure testing and qualification procedures are funded and conducted to qualify technically and economically suitable substitute materials and processes.
- Approve the use of alternatives where they can perform adequately for the intended application and operating environment. Where Cr^{6+} is produced as a by-product from use or manufacture of other acceptable chromium oxides, explore methods to minimize Cr^{6+} production.
- Update all relevant technical documents and specifications to authorize use of the *qualified* alternatives and, therefore, minimize the use of materials containing Cr^{6+}.
- Document the system-specific Cr^{6+} risks and efforts to qualify less toxic alternatives in the Programmatic Environment, Safety, and Occupational Health Evaluation for the system. Analyses should include any cost/schedule risks and life cycle cost comparisons among alternatives. Life cycle comparisons should address material handling and disposal costs and system overhaul cycle times/costs due to any differences in corrosion protection.
- Share knowledge derived from research, development, testing and evaluations (RDT&E) and actual experiences with qualified alternatives.

Chrome Reduction Plan

Description:

- Reduce Cr(VI) and all Cr use and waste

Approach

- Review Cr(VI) usage in DoD to identify applications.
- Develop Strategic Implementation Plan for Cr(VI) and other Cr oxidation states reduction throughout AF.

Benefits

- Reduce Cr(VI) applications in order to improve compliance to EPA, DoD, and other federal, state, and local directives.
- Addresses Executive Order 11514, CAA, CWA, RCRA, NESHAP, AFI32-7040, and AFI 32-7042, and State hazardous reduction plans.

Weapon Systems:

- Various aircraft components - especially landing gear, wheels, hydraulic components, fasteners; vehicles; ground support equipment.

Stakeholders:

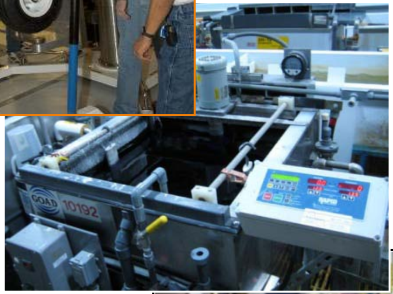
- USAF (e.g., B-1, F-16, F-18, F-22, F-35, C-5, C-17 POs, Space); ANG; Army aircraft, TACOM; NAVAIR; Coast Guard, NASA, DSCC, OEMs.

Current Air Force's Cr (VI) Related Technologies

Coatings & Processes - Cr (VI) Reduction Plan

➢ **Inorganic Coatings**

- Next Generation Non-Line of Sight Coatings
- Dichromate Sealer Replacement
- Cr-free Conversion Coating for Zn-Ni Plating Lines
- Cr-free Conversion Coating for Aluminum Alloys



Drivers: EO 13423; CAA, CWA, RCRA, OSHA; Cr6+ minimization/elimination in acquisition policy memorandum from DUSD J.J. Young, Jr; OSD Emerging Contaminants Watch List; foreign environmental regulations.

Current Air Force's Cr (VI) Related Technologies

Coatings & Processes - Cr (VI) Reduction Plan

- **Organic Coatings**
  - **Cr Free Integration Plan**
    - Status of Cr Free Coating Systems
  - **UV Curable Coatings**
    - Topcoats; Primer; One Coat
    - Explosion Proof UV Lamp
    - UV Paint Booth
  - **Paint / Depaint Life Cycle Extension**

Drivers: EO 13423; CAA, CWA, RCRA, OSHA; Cr6+ minimization/elimination in acquisition policy memorandum from DUSD J.J. Young, Jr; OSD Emerging Contaminants Watch List; foreign environmental regulations.

Next Generation NLOS Alternatives Replace Hard Cr Coatings

- Identify and evaluate a more environmentally acceptable plating process to deposit metallic coatings on aircraft, vehicles, and ground support equipment.

- Identified 60+ candidate drop-in EHC replacements for NLOS/ANLOS applications and performed screening tests on 20+ candidates since 1999

- Best-performing NLOS candidates:
  - ✓ electroless Ni-P + SiC
  - ✓ electroplated nano-Co-P
  - ✓ electroplated Co-P + SiC

- Showing potential, but requiring more optimization
  - ✓ Electroless Ni-P + diamond
  - ✓ Electroplated nano-Co-P + B_4C

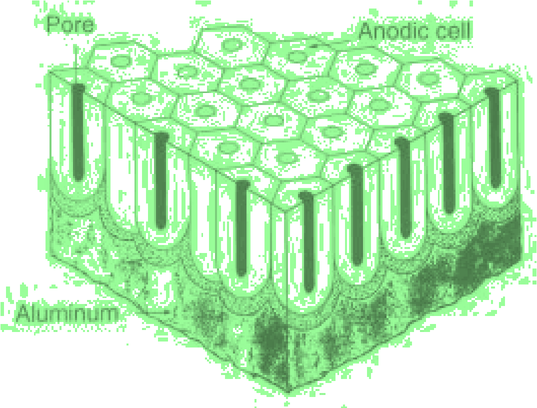
Path Forward

- **Continue coordinating with LG manufacturer to evaluate candidate coatings and transition technology**
- **Conduct Phase II screening testing**
  - **hydrogen embrittlement, fatigue debit, coating of advanced geometries, strippability**
- **Develop transition plan of alternative coating to depot/ALC operations based on positive results of NLOS/ANLOS efforts**
  - **Working with OC-ALC (Tinker) and vendors to alleviate any transition issues related to licensing**
- **Coordinate with other ALCs to ensure that AFRL efforts can address ALC needs to replace EHC**

Dichromate Sealer Replacement

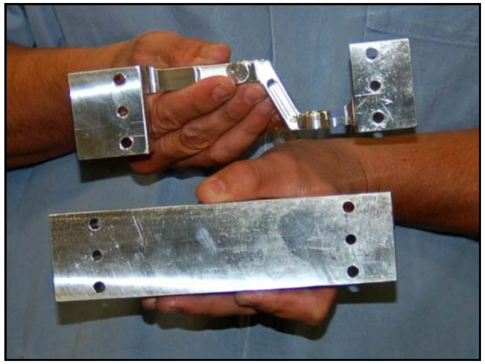
- Identify, evaluate, and facilitate technology insertion of a replacement for the dichromate sealer currently used on anodized landing gear

  - **Identified available/emerging sealing technologies**
  - **Selected 3 of the most promising candidates for lab testing**
  - **Completed testing:**
    - ✓ **All sealers passed quality, thickness, coating weight, and dry adhesion tests**
    - ✓ **Mixed results for wet adhesion tests: considered a marginal pass**
    - ✓ **Nearly all sealers passed corrosion testing**



Path Forward

- **Modify Technical Order 42C2-1 and transition to a new sealer alternative to OC-ALC (Tinker)**
- **Promote transition of an alternative sealer into other ALCs**
- **Disseminate Results to other Services for Implementation**
  - Army Aviation and Missile Command, G-4 Environmental Division is interested in results



Anodized T-38 aileron levers

Chromium-Free Conversion Coatings

- Identify and evaluate chromium-free conversion coatings (CFCCs) for two ALC operations
  1. Use Cr(VI)-containing chromate conversion coatings (CCCs) as post treatments on aluminum (Al) alloys, magnesium (Mg) alloys, ion vapor deposited Al, and Cd coatings
  2. Use trivalent chromium [Cr(III)] conversion coating (CC) on Dipsol IZ-C17+ zinc-nickel (Zn-Ni) coating

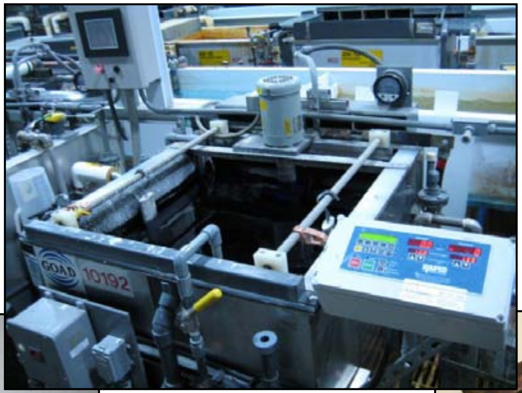
- Ensure sufficient corrosion protection and adequate surface preparation for subsequent processing

- Ensure that throughput is maintained or improved

Non-Cr Conversion Coatings for Zn-Ni Line

➢ Identify and evaluate a non-chrome conversion coatings to replace Cr(III) conversion coating used on Dipsol IZ+ Zn-Ni coating

- Obtained (limited) Zn-Ni qualification data from OO-ALC
- Identified 9 products applicable to Zn and Zn alloys
- Selected 3 most promising candidates for Phase I evaluation



Cr-free Conversion Coatings for Aluminum Alloys

➢Identify and evaluate alternatives to replace the chromium-based conversion coating for treatment of aluminum alloys at OC-ALC

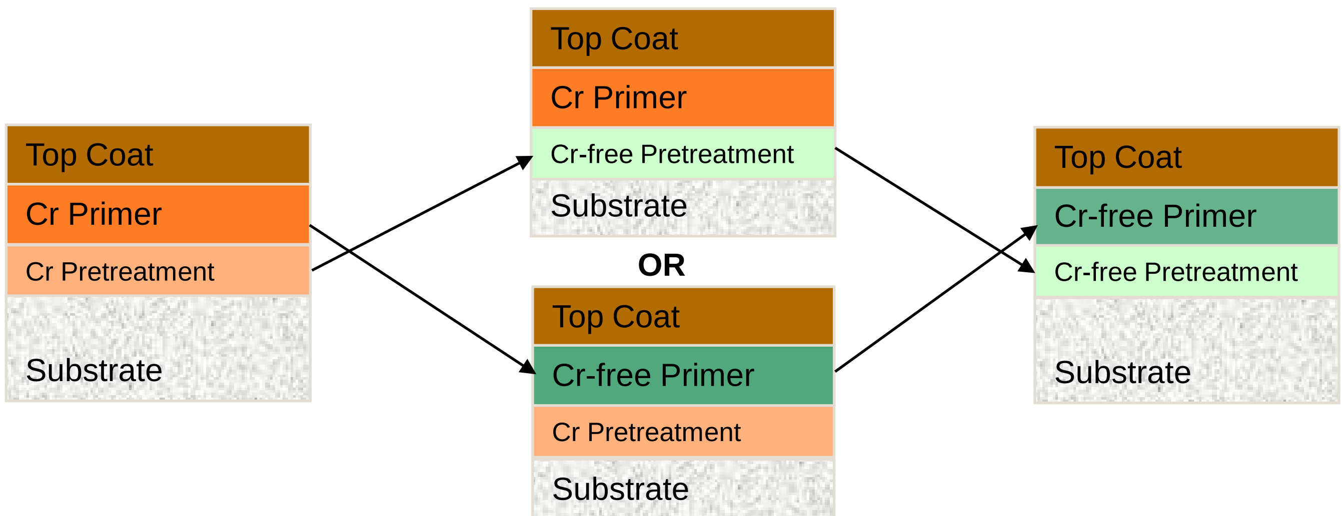
- Conduct technology assessment to identify suitable Cr-free conversion coating;
- Perform testing on the most promising alternatives;
- Conduct technology transfer activities

Path Forward

- For Zn-Ni, select substrates and alternatives + Cr(III) baseline for Phase I trials
  - Review ALC requirements against CFCC supplier candidates
- For Al, complete review of available alternatives
- Define testing and test specimens in collaboration with AFRL and ALCs
- Conduct screening and performance tests

AFRL Chromium-free Coating Systems Integration Plan

No qualified, completely chromium-free system yet ...



← **Yesterday** **2011** **Tomorrow** →

- Some individual chromium-free components cannot be combined with some MIL SPEC or other components; e.g., PreKote with Deft 02-GN-084
- AFRL currently testing two chromium-free coating systems that show most promise based on screening/performance testing

Current Non-Chrome Primers

Pretreatment/Primer	Vendor Data	Gov't Lab Data	Outside Exposure	Field Testing	Mil-Spec Qualification	Weapon System Approval
Alodine 1200/02-GN-084	✓	✓	✓	✓	✓	
Alodine 1200/44-GN-098	✓		✓		✓	
Trivalent chrome/02-GN-084	✓	✓	✓			
5200/ Sicopoxy	✓	✓	✓	✓		
PreKote/Mg Rich (AeroDur 2100)	✓	✓	✓			
RECC 1015 /RECC 3021/02-GN-093	✓			✓		F-15 Approved
5200/53055GEP/1736CEH	✓	✓				
EAP9/CA7236	✓	✓				

Alodine 1200 / 02-GN-084 or 44-GN-98

Systems have Cr(VI) in pretreatment –

Will still need waiver

Alodine 1200 / 02-GN-084

- **Primer Manufacturer – Deft**
- **Solvent borne primer, Praseodymium inhibitor**
- **Qualified to MIL-PRF-23377 Class N with a Chrome Conversion Coating (CCC), Used fleet wide on F-15 with Alodine 1200 CCC and Deft ELT (APC) until Jan 2010**

Alodine 1200 / 44-GN-98

- **Primer Manufacturer – Deft**
- **Water borne primer, Praseodymium inhibitor**
- **Qualified to MIL-PRF-85582 Class N with a Chrome Conversion Coating (CCC), Used on JSF with Alodine 1200 (CCC)**

Trivalent Chrome/02-GN-084

<u>Trivalent Chrome/ 02-GN-084</u>

- **Trivalent Chrome Pretreatment - developed by US Navy and licensed to manufacturers**
  - **Not qualified to a specification**
- **Primer Manufacturer – Deft**
  - **Solvent borne primer, Praseodymium inhibitor**
  - **Primer Qualified to MIL-PRF-23377 Class N with a Chrome Conversion Coating (CCC)**
- **USAF P2 community never supported Trivalent Chrome**
  - **Did not meet EPA requirements**
- **Navy's Recommendation for best Non-Chrome coating system performance**

Alodine 5200 / Sicopoxy

- Primer Manufacturer – Akzo Nobel
- Best performing non-chrome system in RXSC/CTIO laboratory testing (2007)
- In field test on a T-38 since Sept 2008 @ Randolph AFB
  - Good after 200+ flight Hours
- Failed Daytona Beach Testing
- Passed West Jefferson, OH outdoor exposure testing
- Not recommended for moderate to severe corrosion environments
- Akzo Nobel discontinuing manufacture

PreKote / Mg Rich (AeroDur 2100)

- **Pretreatment Manufacturer – Pantheon Chemical**
  - **Approved for use in T.O. 1-1-8 with a chrome primer**
  - **PreKote used on F-16, T- Jets (AETC) since mid ‘90s, Hill AFB since ‘05, C-5 & C-130’s @ Robins AFB**
- **Primer Manufacturer – Akzo Nobel**
  - **Corrosion Inhibitor – Mg particles**
    - Galvanic Corrosion protection
  - **New formulation best lab corrosion test performance to date**
- **System Performs as well as chrome in outdoor exposure on corrosion sensors on aircraft**
  - **Parts flying on CG HH-60 rescue aircraft**
- **Field testing on full aircraft in planning stages (HH-60, C-130, F-16)**
- **System in testing for qualification to MIL-PRF-32239**
- **CTIO’s choice to meet USD, Mr. Young letter**

RECC/02-GN-093

- System Manufacturer – Deft
- DeOX - RECC 1015
- Pretreatment - RECC 3021
- Primer - 02-GN-093
- Vendor only data, no DoD laboratory data
- F-15 Program Office adopted fleet wide, Jan 2011
  - Four F-15's already painted with this system
- System just received by CTIO, will be tested for qualification to MIL-PRF-32239 pending funding

MIL-PRF-32239 Qualification Testing

- **EAP9 / PRC 7236**
  - **System Manufacturer – PPG (PRC DeSoto)**
  - **Topcoats – CA9800 & CA9311**

- **Alodine 5200 / 53055GEP/17036CEH**
  - **Primer Manufacturer – Hentzen Coatings**
  - **Topcoat - 35515APX/35502CMU**
  - **System failed Boeing Long Beach testing**

- **Systems in testing for qualification to MIL-PRF-32239**

Low Temperature Cure Powder Coating

OO-ALC, AFMC/A4
(Joint ESTCP project with NAVAIR)

Description:

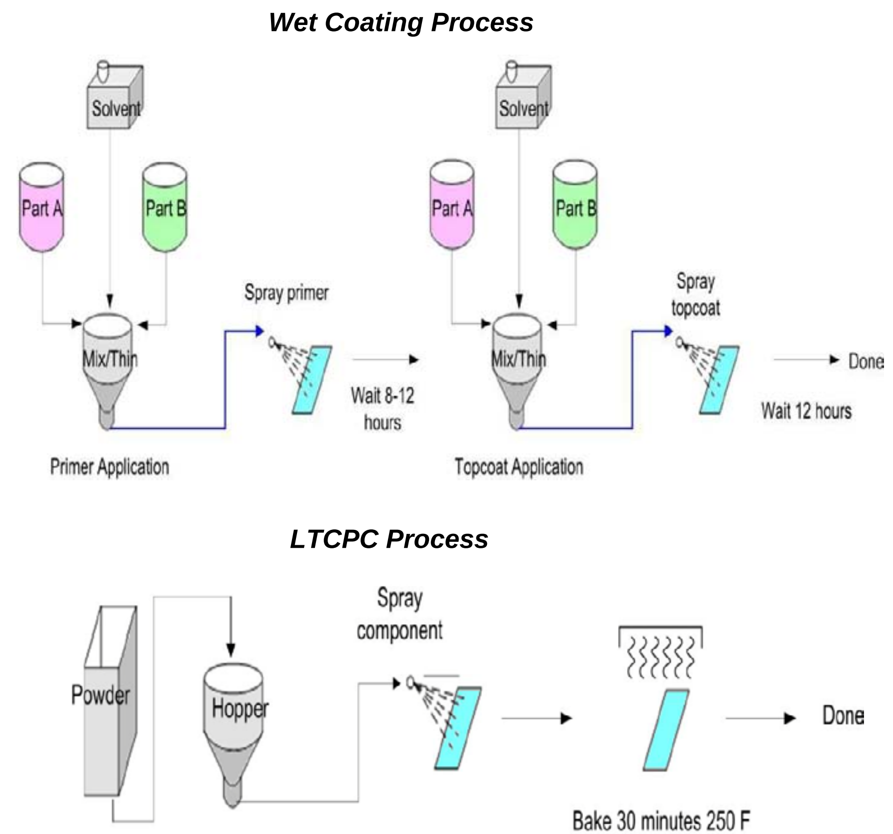
- Demonstrate, validate, and implement a VOC/HAP-free low temperature cure powder coating on DoD weapon system components in a depot production environment

Approach

- Limited laboratory testing to verify performance of the SERDP powder
- 18 month field service evaluation period to assess real-world performance

Benefits

- Reduce/eliminate VOC/HAP emissions
- Eliminate paint overspray and hazardous waste generation
- Reduce/eliminate rework
- Improve depot flow-times
- Reduce handling and storage and worker exposure to known carcinogenic materials



Ultra-Violet Cured Coatings for Aerospace Applications

➢Demonstrate, validate, and implement ultraviolet (UV)-curable coatings as an alternative to the coatings currently used on aerospace equipment

- Identify commercially available and promising coatings emerging from R&D.
- Conduct laboratory testing to verify coating performance
- Evaluate curing lamp technology.
- Perform field service evaluations.
- Implement coatings at depot and field.

Benefits

! Can be applied through traditional coating techniques
! No Cr, No HAPs or VOCs
! Reduce waste
! Cure time measured in minutes versus hours/days

Paint / De-paint
Life Cycle Extension

Description:

- Extend service life of coatings on B-52 aircraft serviced at Oklahoma City Air Logistics Center (OC-ALC)
- Goal – eliminate scuff sand & overcoat at 4 year point
  - B-52 Current Paint Cycle
  - Four Year Mark - scuff sand & overcoat
  - Eight Year Mark - chemically strip and repaint

  (every other Depot cycle)

Approach:

- Develop test plan and conduct coating evaluation activities
- Evaluate coating condition at various intervals
- Identify inspection techniques
  - Validate & document coating performance
  - Decide whether to eliminate scuff sand & overcoat

Reduce Cr(VI) usage and air emissions

Weapon Systems:

- B-52

Stakeholders:

- OC-ALC

Summary

- **Cr(VI) is an excellent corrosion inhibitor and highly toxic**

- **National & International regulations and procedures are tightening on Cr(VI) use**

- **AFRL has a multi-faceted program to eliminate the use of Cr (VI)**

- **AFRL Successes Include:**
  - ***Dichromate Sealers – ready to submit recommendations for TO modifications and transition selected alternative sealer to OC-ALC;***
  - ***Mg-rich Primer Coating System – Ready for Implementation;***
  - ***NLOS Alternatives – Demonstration of Successful Candidates***
- ***AFRL Current Challenges:***
  - ***Conversion Coatings :***
    - ***There is no magic solution,***
    - ***AF direction – Eliminate Cr completely - no Cr(III),***
    - ***AFRL programs with OO- and OC-ALCs just initiated***

- **AFRL is well poised for to meet the future requirements to eliminate Cr(VI)**

2009 AKC Champion
2010 AKC Ranking – 23/24
2011 AKC Grand Champion

Way Ahead – Next Generation

Optimization & Evaluation of Chromium-free Coating Systems

Description:

- Evaluate best alternative Cr-free coating system identified in prior laboratory testing
  - Non-chromate pretreatment
  - Chromium-free primer
  - Conventional advanced performance topcoats

Approach

- Add new coating candidates to testing matrix as they become available. Use corrosion sensors in laboratory and outdoor testing, as well as on aircraft. Monitor corrosion indices at the selected field trial sites. Consider other uses for Cr-free coating systems, such as on ground support equipment, ammunition boxes, vehicles and transporters, and structures.

Weapon Systems:

- T-38, F-16, HH-60, and other fixed and rotary wing aircraft; ground support equipment TBD.

Stakeholders:

- USAF (e.g., AETC, ALCs, B-1, C-5, C-17, F-16, F-18, F-22, F-35 POs, Space Command, GOCOs); ANG; Army aircraft, TACOM; NAVAIR; Coast Guard; NASA; OEMs.

T-38 approved for field trials

Non-Cr paint systems applied to A-10 and KC-135 Aircraft